



## **CRITICAL EARTH OBSERVATION PRIORITIES**

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### **GEO TASK US-09-01a**

#### **Climate Societal Benefit Area**

***Revised Report to the  
GEO User Interface Committee***

Prepared by  
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31 August 2009

## **Group on Earth Observations**

### **GEO Task US-09-01a: Critical Earth Observation Priorities for Climate SBA**

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## **Group on Earth Observations**

### **GEO Task US-09-01a:**

### **Critical Earth Observation Priorities for Climate SBA**

#### **Summary**

The goal of GEO Task US-09-01a is to identify the critical Earth observations for various societal benefit areas (SBAs). This analysis focused on identifying those requirements for the Climate SBA. The analysis covered three sub-areas: the atmosphere, the oceans, and terrestrial processes. The analysis also identified priorities for global climate observations and for regional observations as documented in source material representing international, regional, and national requirements. An international Advisory Group of seven members assisted in identifying source documents and their review.

The socially beneficial uses of climate observations and information about them are wide ranging. In describing the Climate SBA, the GEO notes that climate “has impacts in each of the other eight societal benefit areas” (*GEOSS 10-Year Implementation Plan*, Section 4.1.4). This analysis was limited to a “top down” approach focused on international and regional priorities. Instead of taking a specific topic such as water management or agriculture and identifying that sector’s priority climate-related observations, the analysis used documents authored under the auspices of organizations, regions, and countries that examined the topic of climate broadly. These documents compiled overall global, national, and regional observation requirements.

The analysis used literature and internet searches and Advisory Group recommendations to identify documents for two purposes: (1) to compile a list of Earth observation requirements, and (2) from this list, to extract the requirements that appeared to have the highest priority. These steps were carried out for both global and regional observations.

After evaluating 42 documents for their applicability to the task, 40 were identified that provided relevant information for the priority setting analysis.

Observation requirements were extracted from these documents for the three sub-areas, including 29 documents for global and 18 for regional requirements (some documents included requirements for both global and regional). From these, 16 documents had relevance for identifying global priorities for the sub-areas, and 15 documents for regional priorities in the sub-areas and for 9 geographic regions. Consensus reports previously compiled by international organizations were the main source for identifying global requirements for all sub-areas, including observations specified as essential climate variables (ECVs) by the Global Climate Observing System (GCOS) and its supporting agencies. Additional documents provided information with which to identify a subset of the ECVs as particularly high priority for regional and national requirements.

The method for identifying these priorities was bibliometric (see OTA 1986) and involved simple counts and tabulations of the relative frequency with which specific requirements were cited in the source material. Adjustment was made to avoid double-counting citations appearing in material with common sets of authors or produced by overlapping working groups. Discussion of advantages and limitations of this approach are also included in this report.

At present, with a few exceptions, comprehensive and detailed information on regional and national scale priority observations has yet to be collected and assembled. The priorities identified in this report are drawn from a very small number of documents. The gap is recognized in the literature and noted further in this report.

The result of this analysis is a list of priority observations for both the global and regional dimensions of the climate SBA. The analysis finds that observations of global and regional priority intersect but do not fully overlap. Global priority observations reflect the geographic breadth of the climate as an Earth system. Examples are atmospheric concentrations of greenhouse gases, earth radiation and surface radiation budgets, many types of observations of the oceans, and other variables determined by carbon, hydrological, and other global cycles. Regional priorities center on terrestrial processes including river discharge, lakes, and groundwater – observations with more local and perhaps more immediate relevance as perceived by national decisionmakers. Other priority observations, such as precipitation extreme events, land cover, sea-ice, and aerosols, are common at both geographic scales.

## GEO Task US-09-01a: Critical Earth Observation Priorities for Climate SBA

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## **GEO Task US-09-01a: Critical Earth Observation Priorities for Climate SBA**

### **1 Introduction**

This report articulates Earth observation priorities for the Climate SBA based on an analysis of 42 publicly available documents, including documents produced by Group on Earth Observations' Member Countries and Participating Organizations.

#### **1.1 Group on Earth Observations**

The Group on Earth Observations (GEO)<sup>1</sup> is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS)<sup>2</sup>. GEOSS builds on national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, in situ, airborne, and space-based instruments.

GEO is focused on enhancing the development and use of Earth observations in nine Societal Benefit Areas (SBAs): agriculture, biodiversity, climate, disasters, ecosystems, energy, human health, water, and weather.

#### **1.2 GEO Task US-09-01a**

The objective of GEO Task US-09-01a is to establish and conduct a process to identify critical Earth observation priorities within each SBA and those common to the nine SBAs. Many countries and organizations have written reports, held workshops, sponsored projects, conducted surveys, and produced documents that specify Earth observation needs. In addition, researchers and practitioners have also identified and recommended key Earth observation needs in publications and peer-reviewed literature. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these *existing* materials and analyzing across the materials to determine the priority observations.

This task considers all types of Earth observations, including ground, in situ, airborne, and space-based observations. The task includes direct measurements and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of user types and communities in each SBA, including observation needs from all geographic regions with significant representation from developing countries.

GEO will use the Earth observation priorities resulting from this task to determine, prioritize, and communicate gaps in current and future Earth observations. GEO Member Countries and

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<sup>1</sup> GEO Website: <http://www.earthobservations.org>

<sup>2</sup> GEO 10-Year Implementation Plan: <http://www.earthobservations.org/documents.shtml>

Participating Organizations can use the results in determining priority investment opportunities for Earth observations.

### **1.3 Purpose of Report**

The primary purpose of this report is to articulate the critical Earth observation priorities for the Climate SBA. The intent of the report is to describe the overall process and specific methodologies used to identify documents, analyze them, and determine a set of Earth observation parameters and characteristics. The report describes the prioritization methodologies used to determine the priority Earth observations for this SBA. The report also provides information on key challenges faced, feedback on the process, and recommendations for process improvements.

The primary audience for this report is the GEO User Interface Committee (UIC), which is managing Task US-09-01a for GEO. The GEO UIC will use the results of this report in combination with reports from the other eight SBAs. The GEO UIC will perform a meta-analysis across all nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. Based on the nine SBA reports, the GEO UIC will produce an overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future.

The report's authors anticipate that the GEO Secretariat, Committees, Member Countries, Participating Organizations, Observers, Communities of Practice, and the communities associated with the Climate SBA are additional audiences for this report.

### **1.4 Scope of Report**

This report addresses the Earth observation priorities for the Climate SBA. In particular, this report addresses the sub-areas of the atmosphere, the oceans, and terrestrial processes within the Climate SBA (see Section 3 for more details). The socially beneficial uses of climate observations and information about them are wide ranging. The GEOSS 10-Year Plan describes the Climate SBA as an SBA that “has impacts in each of the other eight societal benefit areas.” To focus this report, its analysis was limited to a “top down” approach to identify international and regional priorities.<sup>3</sup> Instead of taking a specific topic such as water management or agriculture and identifying that sector's priority climate-related observations, the analysis used documents authored under the auspices of organizations, regions, and countries that examined the topic of climate broadly.

The report provides some background and contextual information about the Climate SBA. However, this report is not intended as a handbook or primer on the Climate SBA and a complete description of the Climate SBA is beyond the scope of this report. Please consult the GEO website referenced above for more information about the Climate SBA.

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<sup>3</sup> The focus on a “top down” approach was selected at the direction of the GEO User Interface Committee co-chair, Dr. Lawrence Friedl.



The report focuses on the Earth observations within the Climate SBA, independent of any specific technology or collection method. Thus, the report addresses the “demand” side of observation needs and priorities. The report does not address the specific source of the observations or the sensor technology involved with producing the observations. Similarly, any discussions of visualization tools, decision support tools, or system processing characteristics (e.g., data format, data outlet) associated with the direct use of the observations are beyond the scope of this report.

In this report, the term “Earth observation” refers to parameters and variables (e.g., physical, geophysical, chemical, biological) sensed or measured, derived parameters and products, and related parameters from model outputs. The term “Earth observation priorities” refers to the parameters deemed of higher significance than others for the given SBA, as determined through the methodologies described within. The report uses the terms “user needs” and “user requirements” interchangeably to refer to Earth observations that are articulated and desired by the groups and users in the cited documents. The term “requirements” is used generally in the report to reflect users’ wants and needs; the use in this report does not imply technical, engineering specifications.

Following this introduction, the report discusses the overall approach and methodologies used in this analysis (Section 2). Section 3 describes the Climate SBA and the specific sub-areas that were part of the analysis. Section 4 articulates the specific Earth observations for each Climate sub-area, and Section 5 presents the priority observations across the Climate SBA. Sections 6 and 7 present additional findings from the analysis of the documents and any recommendations. The Appendices include the documents cited and sourced as well as additional information describing aspects of the Climate SBA.

## **2 Methodology**

This section documents the general process followed and specific methodologies used to identify documents, analyze them, determine Earth observation parameters and characteristics, and establish a set of priority Earth observations for this SBA.

### **2.1 Task Process**

The GEO UIC established a general process for each of the SBA analysts to follow in order to ensure some consistency across the SBAs. This general process for each SBA involves nine (9) steps, as summarized in the following list:

- Step 1: Identify Analyst and Advisory Group for the SBA
- Step 2: Determine scope of topics within the SBA
- Step 3: Identify documents regarding observation priorities for the SBA
- Step 4: Develop analytic methods and priority-setting criteria
- Step 5: Review and analyze documents for priority Earth observations needs
- Step 6: Combine the information and develop a preliminary report

- Step 7: Gather feedback on the preliminary report
- Step 8: Perform any additional analysis
- Step 9: Complete the report on Earth observations for the SBA.

A detailed description of the general US-09-01a process is available at the Task website <http://sbageotask.larc.nasa.gov> or GEO website. Some steps in the process occurred simultaneously or iteratively, such as identifying documents (Step 3) and reviewing documents (Step 5).

## **2.2 Analyst and Advisory Group**

The Climate SBA had an “Analyst” and an “Advisory Group” to conduct the process of identifying documents, analyzing them, and prioritizing the Earth observations. The Analyst served as the main coordinator to manage the activities.

### **2.2.1 Analyst**

For the Climate SBA, the Analyst was Molly Macauley. She is a senior fellow at Resources for the Future (RFF). (RFF is a nonprofit research organization in Washington, DC, established in 1952 at the request of the President of the United States to assess global and national natural resources.) Dr. Macauley’s research expertise includes policy and economic analysis of natural resources. She was previously a lead author for synthesis reports under the US Climate Change Science Program and serves on several advisory boards providing expertise on climate and Earth observations policy, including those of the US National Oceanic and Atmospheric Administration, the US National Aeronautics and Space Administration, and the National Academy of Sciences. She also leads an international research team on Earth observations of forests and forest carbon.

Dr. Macauley prepared this report under a subcontract to Resources for the Future from Battelle Memorial Institute, Columbus, Ohio.

### 2.2.2 Advisory Group

The Advisory Group for the Climate SBA consisted of seven (7) scientific, technical, and programmatic experts from the field of climate analysis. Table 1 lists the Advisory Group members.

**Table 1. Advisory Group for Climate SBA.**

Name	GEO Country or Organization	Affiliation	Geographic Region/Country
Kwabena A. Anaman	Ghana	Institute of Economic Affairs	Africa
Ghassam Asrar	World Climate Research Program	World Climate Research Program	Global
Stephan Bojinski	World Meteorological Organization	World Meteorological Organization	Global, Europe
Greg Flato	Canada	Environment Canada	North America
Mitch Goldberg	USA	National Oceanic and Atmospheric Administration	North America
Teruyuki Nakajima	Japan	University of Tokyo	Asia
Alexander Zaytsev	Russia	Voeikov Main Geophysical Observatory	Russia

The Analyst identified the Advisory Group (AG) members through literature searches, personal contacts, and references. The AG includes members from two international organizations, five countries, and four continents, including one from a developing country.

The primary roles of the AG were to assist in identifying documents, assess methodology and analytic techniques, assess prioritization schemes, review findings, and review the report. The primary contact with the AG was through email. The AG did not meet in person during the course of the analysis.

## 2.3 Methodology

This section provides a general description of the processes, analytic methods, and approaches the analyst and advisory group used to identify documents, analyze them, and establish a set of priority Earth observations. As noted in the Introduction, two types of priorities emerge as relevant for the climate SBA. One is priority observations for understanding the global climate system. The other is priority observations for understanding the effects of climate at the regional scale.

### 2.3.1 Documents

The analysis used literature reviews, internet searches, and Advisory Group recommendations to identify documents with information related to observation requirements. International working groups and intergovernmental agencies have previously compiled information about global Earth observation requirements for climate, and their reports are included in the analysis. These include reports by the World Meteorological Organization (WMO) and experts working under

the auspices of the Global Climate Observing System (GCOS). The documents also include assessments by the Intergovernmental Panel on Climate Change (IPCC) of the United Nations Framework Convention on Climate Change (UNFCCC). Reports by regional and national working groups and agencies provided information about regional requirements. These documents include reports of regional workshops and assessments by national meteorological and environmental agencies. Mission planning documents for future Earth observation systems were also a source of information about priority requirements.

### **2.3.2 Analytic Methods**

Each document was evaluated for its usefulness in describing specific observation requirements. The extracted information was inventoried and compiled into a single master database listing all requirements and documenting all sources. The information was then organized into three Climate sub-areas (described below) for global and regional requirements for each sub-area.

### **2.3.3 Prioritization Methods**

The prioritization method involved two steps.

The first step was documentation of an already-determined set of climate observation priorities, the essential climate variables (ECVs) identified by international teams of climate science and related experts convened under the auspices of the GCOS.

The second step was review of documented requirements, both included among and in addition to the ECVs, to identify priorities of additional users. The analyst anticipated that the priorities of these users may overlap with the ECVs, but by taking account of their specific requirements, the needs of these users could provide a sense of relative priority, for these users, among the ECVs. As described further in Section 3.4, these users include regional and national governments.

In this second step, the method for assigning priority used well-known bibliometric methods (OTA, 1986). Priority was indicated by the relative frequency with which an observation was cited by the documents as a required climate observation.

For identifying global priorities, and using the master database of all required observations generated during the document review, a simple count was taken of the number of documents in which a particular Earth observation was described in the document as a required observation. This value was divided by the total number of documents in which global requirements are discussed.

For the regional priorities, the count was taken of the number of regions for which an observation was described as a priority (for example, the number of regions for which extreme precipitation observations is required). This value was divided by the total number of possible regions. Several of the documents describe requirements for multiple regions. Appendix C identifies reports containing regional information.

Examples:

Precipitation as a global observation: Precipitation is cited in four documents as a required observation (in addition, it is on the list of ECVs). There are 16 documents, in addition to those identifying the ECVs, in which global requirements are discussed. The portion of citations for the observation of precipitation is  $4/16 = 0.3 = 30\%$ .

Precipitation as a regional observation: Precipitation is cited in the documents as a required observation for four regions. There are nine possible regions. The percentage of citations for the observation of precipitation is  $4/9 = 0.4 = 40\%$ .

### 2.3.4 Discussion of the Prioritization Methodology

The prioritization approach assumes that frequency of citation is correlated with “significance” in the context of the analysis.<sup>4</sup> There are several widely recognized limits to bibliometric approaches (for example, see discussion in OTA 1986) and these limits serve as caveats to the prioritization results.

Limitations of the approach include:

- (1) the size, representativeness, and quality of the sample of documents reviewed,
- (2) the interpretation of a “citation,” and
- (3) the weight given to each citation and each document.

To address the first limitation, the size, representation, and quality of the documents assembled for this analysis were the result of an extensive search by the analyst together with the additional assistance of the Advisory Group to identify and locate publicly available materials. Most of the documents were authored by teams of experts collaborating in high-level working groups, widening representation of priorities beyond those that might be conveyed by an individual author. Fewer documents were available than necessary to provide a large sample size, however. The number of documents, particularly for each region, was often just one or two. Initiatives are now underway among regional and national working groups to identify their priorities (for example, the IPCC has urged enhanced understanding of regional needs (see WMO 2008a) and the World Climate Research Program (WCRP) and other organizations are regularly convening regional workshops (see WCRP 2009)).

In interpreting a “citation” and weighing its relative priority among all of the documents, the citations were extracted from the subset of these documents that described required observations in the context of decisionmaking for global and regional needs. To the extent the documents are comprehensive, the specific requirements they identify can be interpreted as representing

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<sup>4</sup> Strictly speaking, bibliometrics is an approach used to identify citations and then count and relate them in a “map of science” for the purpose of quantitatively measuring areas of relatively “greater contribution.” See OTA (1986).

requirements of some if not high priority. The weight given to each citation and document assumes that each of the documents and each of the regions are equally relevant in assigning priority.

### **3 Climate SBA**

This section provides summary information of the Climate SBA and the specific sub-areas. This section also discusses the specific documents used in the meta-analysis (general discussion rather than specifics on each document) and the broad user-types within the SBA.

#### **3.1 Climate SBA Description**

The following is the brief statement of topics covered and key outcomes in the Climate SBA from the GEOSS 10-Year Implementation Plan, Section 4.1.4:

*“The climate has impacts in each of the other eight societal benefit areas. Coping with climate change and variability demands good scientific understanding based on sufficient and reliable observations. GEOSS outcomes will enhance the capacity to model, mitigate, and adapt to climate change and variability. Better understanding of the climate and its impacts on the Earth system, including its human and economic aspects, will contribute to improved climate prediction and facilitate sustainable development while avoiding dangerous perturbations to the climate system.”*

The Climate SBA includes three sub-areas, each describing a part of the physical Earth system and its climate processes: the atmosphere, the oceans, and terrestrial processes. IPCC (2007a, b, c) and CEOS (2006), together with most of the documents used in this analysis, identify these as sub-areas representative of the physical climate system. Although the analysis addresses the sub-areas separately, the documents share a common theme emphasizing that the areas and in particular, their interactions, necessarily combine to describe Earth and its climate as a *system*.

#### **3.2 Sub-areas**

**The atmosphere (over land, sea, and ice):** This sub-area characterizes Earth’s surface and upper-air processes and phenomena such as temperature, wind speed, and water vapor. It also includes atmospheric composition such as gases and aerosols.

**The oceans:** This sub-area includes the ocean surface such as sea-surface temperature, sea level, and sea ice. It also includes below surface (sub-surface) variables such as salinity, current, and carbon concentration.

**Terrestrial processes:** This sub-area includes the area of snow cover, changes in glaciers and ice caps, and land cover.

Detailed description of the sub-areas and their interactions is in IPCC (2007c).

### 3.3 Documents

Preparation of this report has benefited from consensus reports previously compiled by international organizations of experts and identifying priority global climate observations termed essential climate variables. The organizations participating in determination of these variables include but are not limited to the WMO, the WCRP, the GCOS, the Committee on Earth Observations Satellites (CEOS), the Global Ocean Observing System (GOOS), the Global Terrestrial Observing System (GTOS), and GEO Member countries and other Participating Organizations. Twelve of the most recent of these reports compiled during 2006 to the present were included in this analysis as source material providing both background and context. The ECVs described in these reports are included in the list of priority observations reported below.

The 29 additional documents collected and used in this analysis include international, regional-, and national-level government and working group reports, conference reports, and mission planning documents for future Earth observing instruments. Table 2 summarizes the documents.

**Table 2. Document Sources for Climate SBA.**

<b>Geographic Region</b>	<b>Number of Documents *</b>
International	27
Regional – General	3
Africa	2
Asia/Middle East	1
East Asia	1
Europe	3
North America	5
Oceania/Australia	1
South/Central America	1

\* Total exceeds total number of documents because of overlapping regional relevance.

All 42 of the documents were sorted by authorship and on the basis of global versus regional scope. Sorting served three purposes: (1) to assist in matching the types of documents to the types of user groups; (2) to allow comparison of priorities among different authors and between global and regional priorities; and (3) to help to avoid double counting of commonly authored reports in the priority methodology (some documents are authored by common groups of experts). The sorting categories are described briefly in the next paragraphs and summarized in Table 3. The use of the sorting in identifying priorities is described further in Section 5.

- I. **Reports compiled by international organizations of experts for the purpose of understanding global climate processes.** Authorship of these reports is under the auspices of organizations such as the WMO, the WCRP, and the CGOS, including subgroups of GCOS (such as the Global Terrestrial Observing System (GTOS) and the Global Ocean Observing System (GOOS)). These organizations include experts representing GEO member countries and many are GEO participating organizations.



Examples of reports used in this analysis include *Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008* (GCOS 2009b) and *GCOS Essential Climate Variables* (GCOS 2009c).

- II. **Reports compiled by the Intergovernmental Panel on Climate Change (IPCC) for the purpose of understanding the physical and social impacts of climate.** Authorship of these reports is under the auspices of the IPCC and includes experts in the physical sciences and on the impacts of climate on humans, marine and terrestrial ecosystems, agriculture, public health, and freshwater. Reports used in this analysis include *Climate Change 2007: the Physical Science Basis* (IPCC 2007c) and *Report of the Conference of the Parties on Global Observing Systems for Climate* (UNFCCC 2008).
- III. **Reports compiled by organizations in response to IPCC reports and specifically addressing climate observations.** This set of reports bridges a gap between the focus on observations in Category I and the focus on climate impacts in Category II. Authorship of these reports is under the auspices of organizations such as the WMO, the European Space Sciences Committee, and space agencies. As an example, *Future Climate Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report* (WMO 2008a) summarizes a workshop organized jointly by GCOS, the WCRP, and the International Exosphere-Biosphere Program (IGBP) and intended to “help guide future strategies for climate change observations and research” specifically in response to findings by the IPCC about the need to improve understanding of climate impacts.
- IV. **Reports compiled by international, regional, and national organizations to identify priorities for regional climate observations.** Examples of these reports used in this analysis include *Africa Climate Report* (Washington et al., 2004) and *Initial Science Plan of the Monsoon Asia Integrated Regional Study* (Cfu et al., eds 2006).
- V. **Reports compiled by organizations to guide planning for Earth observation missions related to climate.** In planning Earth observation missions, authoring organizations of these reports identify priority observations. Examples include reports on planning for the Global Monitoring for Environment and Security (GMES) Sentinel missions (ESA 2007a,b) and other observing missions (for example, NRC 2007).
- VI. **Other documents.** The “other document” category ranges from published workshop reports defining priorities for the technical attributes of observations (such as spatial resolution, accuracy) to reports by climate experts in the global insurance sector, an international business sector not included specifically in other GEO SBAs and directly working with climate scientists to identify priority observations for integration into their Earth system models.



**Table 3. Document Categories for Climate SBA.**

<b>Document Category</b>	<b>Examples</b>
<b>I</b> International Consensus on Climate Observations	<i>Global Climate Observing System (GCOS) Essential Climate Variables (GCOS 2009c)</i> <i>Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008 (GCOS 2009b)</i>
<b>II</b> Intergovernmental Panel on Climate Change (IPCC) Assessment	<i>Climate Change 2007: The Physical Science Basis (IPCC 2007c)</i> <i>Report of the Conference of the Parties on Global Observing Systems for Climate (UNFCCC 2008)</i>
<b>III</b> Post-2007 IPCC Update	<i>Future Climate Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report (WMO 2008a)</i>
<b>IV</b> Regional Assessment	<i>Africa Climate Report (Washington et al., 2004)</i> <i>Workshop on Evaluating and Improving Regional Climate Projections (WCRP 2009)</i>
<b>V</b> Proposed and Forthcoming Earth Observing Missions	<i>Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond (NRC 2007)</i> <i>GMES Sentinels 4 and 5 mission Requirements Document (issue 1 revision 0) (ESA 2007a,b)</i>
<b>VI</b> Other	<i>Earth Observations: A Catastrophe Risk Modeling Point of View (Khare, 2008)</i>

After evaluating all documents for applicability to the task, 40 were identified that provided relevant information for the priority setting analysis. Observation requirements were extracted from 40 documents for the three sub-areas, from 16 documents for global priorities, and from 15 documents for regional priorities (some documents provided information for more than one of these categories).

The Bibliography lists all source documents; in addition, Appendix C provides further details for all documents, including whether they are international, regional or both in scope and the category to which each document was assigned.

### 3.4 User Types

As described in the scope of this analysis (Section 1.4), the user types identified for the Climate analysis are those whose requirements are “top down,” centering uniquely or substantially on a set of climate observations for global, regional, or broad national purposes rather than for specific sectors such as agriculture or water management. Requirements identified for broad purposes may reflect underlying priorities of sectors important in a region’s economy, but individual sectors are not the focus here.

The first broad type is users engaged in understanding the science of the global climate system in order to inform decisionmakers. These persons include climate modelers, integrated assessment modelers, and the international community contributing to the work of the IPCC. These users

are working to characterize the state of the global climate system and its variability; monitor the forcing of the climate system, including both natural and anthropogenic contributions; support the attribution of the causes of climate change; support the prediction of global climate change; enable projection of global climate change information down to regional and local scales; and enable characterization of extreme events important in impact assessment and adaptation, and to the assessment of risk and vulnerability. The priority observations of these users are for understanding the global carbon and hydrologic cycles and their interactions in the atmosphere, the oceans, and terrestrial processes.

The second broad user type is engaged in policy at the level of regional or national decisionmaking. These users are designing policy for greenhouse gas stabilization and monitoring and for climate change adaptation. They include regional and national governments in both developed and developing countries as well as international intergovernmental organizations. Also included in this group is an additional group of users working with regional governments to identify priorities of global importance. This group is large worldwide insurers seeking to integrate climate observations in their catastrophic loss models, including but not limited to the purpose of assisting developing countries by offering climate-index-based lending.<sup>5</sup>

## **4 Earth Observations for Climate SBA**

The inventories described in this section provided the database from which priorities were derived.

### **4.1 Global Requirements**

Tables 4, 5, and 6 are a comprehensive inventory of all global observations mentioned in all documents and for each sub-area. The tables also identify the major source documents for each entry. For all three sub-areas, the requirements are drawn largely (but not exclusively) from documents in Categories I, II and III.

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<sup>5</sup> This type of index insurance is paid in advance of a catastrophic event such as drought or flood, rather than after the event. Payment in advance allows the insured to take risk-averting action. The actuarial basis of this type of index insurance rests critically on climate observations, and these are direct inputs into the models.

### 4.1.1 Earth Observations for Atmosphere: Global Requirements

Table 4 lists the observations and main source documents for the sub-area atmosphere. These include observations of surface, upper air, and composition variables.

**Table 4. Earth Observations for Climate SBA: Inventory of Global Requirements and Source Documents for Sub-Area Atmosphere.**

Observation	Source Documents
<b>Surface</b>	
<i>Air temperature</i>	GCOS 2009a,c NRC 2007 WMO 2008a
<i>Precipitation</i>	GCOS 2009a GCOS 2006a IPCC 2007a,b,c WMO 2008a
<i>Precipitation extreme events</i>	GCOS 2006a IPCC 2007a,b,c WMO 2008a
<i>Air pressure</i>	GCOS 2009a NRC 2007
<i>Surface radiation budget</i>	GCOS 2009a NRC 2007, 2008
<i>Wind speed and direction</i>	GCOS 2009a GCOS 2006a
<i>Water vapor</i>	GCOS 2009a GCOS 2006a NRC 2007, 2008 WMO 2008a IPCC 2007c
Evaporation and evapotranspiration	WMO 2008a
<b>Upper Air</b>	
<i>Earth radiation budget</i>	GCOS 2009a GCOS 2006a NRC 2008 Ohring 2007 Bojinski 2008 IPCC 2007c
<i>Upper air temperature</i>	GCOS 2009a GCOS 2006a WMO 2008a
<i>Wind speed and direction</i>	GCOS 2009a GCOS 2006a Khare 2008
<i>Water vapor</i>	GCOS 2009a GCOS 2006a IPCC 2007c WMO 2008a ESA 2007b
<i>Cloud properties</i> Cover Ice profile (column) Water profile (column) Top height Top temperature	GCOS 2009a GCOS 2006a IPCC 2007c NRC 2007, 2008 Ohring 2007
<b>Composition</b>	
<i>Carbon dioxide</i>	GCOS 2009a GCOS 2006a WMO 2008a IPCC 2007 a,b,c ESA 2007b Hamazaki 2008
<i>Methane</i>	GCOS 2009a GCOS 2006a WMO 2008a IPCC 2007 a,b,c ESA 2007b Hamazaki 2008
<i>Ozone</i>	GCOS 2009a GCOS 2006a WMO 2008a NRC 2008
<i>Other long-lived greenhouse gases</i>	GCOS 2009a WMO 2008a IPCC 2007 a,b,c ESA 2007b
<i>Aerosol properties</i>	GCOS 2009a GCOS 2006a IPCC 2007c NRC 2007,2008 ESA 2007b
Notes: Italicized observations are GCOS Essential Climate Variables (see text). Italicized documents are source material for technical requirements (see text).	

#### 4.1.2. Earth Observations for Oceans: Global Requirements

Table 5 lists the specific observations and main source documents for the sub-area oceans. These include observations of surface and subsurface variables.

**Table 5. Earth Observations for Climate SBA: Inventory of Global Requirements and Source Documents for Sub-Area Oceans.**

Observation	Source Documents
<b>Surface</b>	
<i>Sea-surface temperature</i>	GCOS 2009a <i>GCOS 2006a</i> IPCC 2007c WMO 2008a NRC 2008 Khare 2008
<i>Sea-surface salinity</i>	GCOS 2009a <i>GCOS 2006a</i> IPCC 2007c WMO 2008a
<i>Sea level</i>	GCOS 2009a <i>GCOS 2006a</i> IPCC 2007c WMO 2008a NRC 2008 Ohring 2007 Bojinski 2008
<i>Sea state</i>	GCOS 2009a <i>GCOS 2006a</i>
<i>Sea ice</i>	GCOS 2009a <i>GCOS 2006a</i> IPCC 2007c NRC 2007, 2008 Bojinski 2008
<i>Current</i>	GCOS 2009a
<i>Ocean color</i>	GCOS 2009a <i>GCOS 2006a</i> NRC 2008
<i>Carbon dioxide partial pressure</i>	GCOS 2009a WMO 2008a Khare 2008
<i>CO<sub>2</sub> flux across air/sea interface</i>	WMO 2008a
<b>Subsurface</b>	
<i>Temperature</i>	GCOS 2009a WMO 2008a
<i>Salinity</i>	GCOS 2009a WMO 2008a
<i>Current</i>	GCOS 2009a
<i>Nutrients</i>	GCOS 2009a
<i>Carbon</i>	GCOS 2009a NRC 2007, 2008 WMO 2008a IPCC 2007c
<i>Ocean tracers</i>	GCOS 2009a
<i>Phytoplankton</i>	GCOS 2009a
Notes: Italicized observations are GCOS Essential Climate Variables (see text). Italicized documents are source material for technical requirements (see text).	

### 4.1.3 Earth Observations for Terrestrial Processes: Global Requirements

Table 6 lists the specific observations and main source documents for the sub-area terrestrial processes. These include observations of snow cover area, area and elevation changes of glaciers and ice caps, albedo, land cover area and change.

**Table 6. Earth Observations for Climate SBA: Inventory of Global Requirements and Source Documents for Sub-Area Terrestrial Processes.**

<b>Observation</b>	<b>Source Documents</b>
<i>Snow cover area</i>	GCOS 2009a <i>GCOS 2006a</i> IPCC 2007c NRC 2008 ESA 2007a
<i>Glaciers and ice caps</i> Area maps Elevation changes	GCOS 2009a <i>GCOS 2006a</i> UNFAO 2008a IPCC 2007c NRC 2007 WMO 2008a
<i>Permafrost and seasonally-adjusted frozen ground</i>	GCOS 2009a IPCC 2007c
<i>Albedo</i>	GCOS 2009a <i>GCOS 2006a</i>
<i>Land cover</i> Type maps Change maps	GCOS 2009a <i>GCOS 2006a</i> Patton 2008 ESA 2007a IPCC 2007a
<i>Fraction of absorbed photo-synthetically active radiation</i>	GCOS 2009a <i>GCOS 2006a</i>
<i>Leaf area index</i>	GCOS 2009a <i>GCOS 2006a</i>
<i>Biomass</i>	GCOS 2009a <i>GCOS 2006a</i> WMO 2008a
<i>Fire disturbance</i>	GCOS 2009a <i>GCOS 2006a</i>
<i>Lakes</i> Level Surface temperature	GCOS 2009a <i>GCOS 2006a</i>
<i>Soil moisture</i>	GCOS 2009a <i>GCOS 2006a</i> IPCC 2007c
<i>River discharge</i>	GCOS 2009a WMO 2008a
<i>Water use</i>	GCOS 2009a IPCC 2007 a,b,c WMO 2008a
<i>Groundwater</i>	GCOS 2009a
<i>Land/soil carbon</i>	NRC 2007 WMO 2008a
Notes: Italicized observations are GCOS Essential Climate Variables (see text). Italicized documents are source material for technical requirements (see text).	

## 4.2 Earth Observations for Climate: Regional Requirements

Tables 7, 8, and 9 are a comprehensive inventory of all regional observations and source documents. The “blank” rows carry over the corresponding rows from Tables 4, 5, and 6. The requirements are drawn mainly but not exclusively from the documents in category IV.

### 4.2.1 Earth Observations for Atmosphere: Regional Requirements

Table 7 lists the observations and main source documents for regional requirements within the sub-area atmosphere. The largest overlap with global requirements is precipitation extreme events, precipitation, air temperature, and aerosol properties.

**Table 7. Inventory of Regional Requirements and Source Documents for Sub-Area Atmosphere.**

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediterranean Basin
<b>Surface</b>									
<i>Air temperature</i>	CGEO 2009 MSCES 2008 NRC 2007				WMO 2006	WMO 2006	WMO 2006		
<i>Precipitation</i>	CGEO 2009 MSCES 2008 NRC 2009 Karl et al 2009		GCOS 2006b	GCOS 2006b				WMO 2006	WMO 2006
<i>Precipitation extreme events</i>	NRC 2009 Karl et al 2009	GEF 2004	GCOS 2006b	GCOS 2006b	Cfu and DeVries 2006		WMO 2006 Salinger et al 2002		WMO 2006
<i>Air pressure</i>	NRC 2007						WMO 2006  Salinger et al 2002		
<i>Surface radiation budget</i>	NRC 2007,2008								
<i>Wind speed and direction</i>							WMO 2006  Salinger et al 2002		
<i>Water Vapor</i>									
Evaporation and evapotranspiration									

**Table 7. (Continued).**

<b>Observation</b>	<b>North America</b>	<b>Central and South America and the Caribbean</b>	<b>Eastern and Southern Africa</b>	<b>Western and Central Africa</b>	<b>South and Southwest Asia</b>	<b>Central East and SE Asia</b>	<b>Pacific Islands</b>	<b>Europe</b>	<b>Mediterranean Basin</b>
<b>Upper Air</b>									
<i>Earth radiation budget</i>									
<i>Upper air temperature</i>									
<i>Wind speed and direction</i>									
<i>Water vapor</i>									
<i>Clouds</i>	CGEO 2009 MSCES 2008 NRC 2007					WMO 2006			
<b>Composition</b>									
<i>Carbon dioxide</i>									
<i>Methane</i>									
<i>Ozone</i>	MSCES 2008								
<i>Other long-lived greenhouse gases</i>									
<i>Aerosol properties</i>	MSCES 2008 NRC 2007		Washington et al 2004	Washington et al 2004	WMO 2006	WMO 2006			
Notes: <i>GCOS Essential Climate Variables in italics (see text).</i>									

#### 4.2.2. Earth Observations for Oceans: Regional Requirements

Table 8 lists the specific observations and main source documents for regional requirements within the sub-area oceans. The overlap with global requirements is largest for sea-surface temperature.

**Table 8. Inventory of Regional Requirements and Source Documents for Sub-Area Oceans.**

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediterranean Basin
<b>Surface</b>									
<i>Sea-surface temperature</i>	NRC 2008, 2009	(Western South Atlantic) WMO 2006	(esp. Western Indian Ocean) WMO 2006 Washington et al 2004	Washington et al 2004	(establish Indian Ocean observing system ) WMO 2006		(monitor tsunamis) WMO 2006		
<i>Sea-surface salinity</i>									
<i>Sea level</i>	NRC 2009 Karl et al 2009						WMO 2006		
<i>Sea state</i>									
<i>Sea ice</i>	CGEO 2009 MSCES 2008 NRC 2007 Karl et al 2009							GEO 2009	
<i>Current</i>									
<i>Ocean color</i>									
<i>Carbon dioxide partial pressure</i>									
CO <sub>2</sub> flux across air/sea interface									



**Table 8. (Continued).**

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediterranean Basin
<b>Subsurface</b>									
<i>Temperature</i>		(Western South Atlantic) WMO 2006							
<i>Salinity</i>									
<i>Current</i>									
<i>Nutrients</i>									
<i>Carbon</i>									
<i>Ocean tracers</i>									
<i>Phytoplankton</i>									
Notes: <i>GCOS Essential Climate Variables in italics</i> (see text).									

#### 4.2.3. Earth Observations for Terrestrial Processes: Regional Requirements

Table 9 lists the specific observations and main source documents for the regional requirements within the sub-area terrestrial processes. These overlap with global requirements with the exception of albedo, fraction of absorbed photosynthetically active radiation, leaf area index, biomass, and land/soil carbon. The most frequently cited requirement is land cover, followed by glaciers and ice caps, lakes, soil moisture, river discharge, water use and groundwater.

**Table 9. Inventory of Regional Requirements and Source Documents for Sub-Area Terrestrial Processes.**

Observation	North America	Central and South America and the Caribbean	Eastern and Southern Africa	Western and Central Africa	South and Southwest Asia	Central East and SE Asia	Pacific Islands	Europe	Mediterranean Basin
<i>Snow cover area</i>	CGEO 2009 MSCES 2008 NRC 2008, 2009					WMO 2006		GEO 2009	
<i>Glaciers and ice caps</i>	CGEO 2009, MSCES 2008	WMO 2006			WMO 2006	WMO 2006		GEO 2009	

**Table 9. (Continued).**

<b>Observation</b>	<b>North America</b>	<b>Central and South America and the Caribbean</b>	<b>Eastern and Southern Africa</b>	<b>Western and Central Africa</b>	<b>South and Southwest Asia</b>	<b>Central East and SE Asia</b>	<b>Pacific Islands</b>	<b>Europe</b>	<b>Mediterranean Basin</b>
<i>Permafrost and seasonally-adjusted frozen ground</i>	MSCES 2008 Karl et al 2009					WMO 2006			
<i>Albedo</i>									
<i>Land cover</i>	NRC 2009*	WMO 2006	(urban) WMO 2006, GCOS 2006b	GCOS 2006b		WMO 2006		ESA 2007a	WMO 2006
<i>Fraction of absorbed photo-synthetically active radiation</i>									
<i>Leaf area index</i>									
<i>Biomass</i>									
<i>Fire disturbance</i>	NRC 2009								
<i>Lakes</i>	NRC 2009		WMO 2006	Washington et al 2004			Salinger et al 2002	WMO 2006	
<i>Soil moisture</i>	NRC 2009		WMO 2006	Washington et al 2004				WMO 2006	
<i>River discharge</i>	Karl et al 2009		WMO 2006	Washington et al 2004			Salinger et al 2002	WMO 2006	
<i>Water use</i>	NRC 2009			Washington et al 2004				WMO 2006	WMO 2006
<i>Groundwater</i>	NRC 2009		WMO 2006	Washington et al 2004			Salinger et al 2002		
<i>Land/soil carbon</i>									
Notes: <i>GCOS Essential Climate Variables in italics</i> (see text).									

## **5 Priority Earth Observations for Climate SBA**

This section contains the results from the prioritization method applied to the observations identified in Section 4. These results draw from documents in all categories, particularly Categories II through VI.

### **5.1 Summary of Results**

Section 2.3.3 described the method for assigning priority. Appendix D shows the frequency results for all of the global and regional observations. A summary of these results is below; for this set of results, the relative frequency chosen to assign priority is a value equal to or greater than the mean frequency value of 0.2 for both global and regional requirements. This value means that 20% or more of the documents for global and regional requirements cite the observation type and it is thus assigned higher priority than other types. Choosing this value is conservative (that is, the value is low) and leads to a larger number of priorities than would a larger value. A conservative approach is chosen for several reasons and these should be kept in mind in interpretation of the priority setting results. These reasons include the physical nature of climate as a system; its complexity and interactions are best understood as a collection of complementary observations (see Section 3.1). Another reason is related to the report methodology: the small number of documents available, particularly on a regional and national basis, leads to two if not even just one document carrying large relative weight.

### **5.2 Priority Observations**

Table 10 shows the global and regional priority observations. It also lists technical attributes, when available. Priorities common to both global and regional observations are shaded in orange. Priorities unique to global observations and to regional observations are shaded in green and yellow, respectively.

### **5.3 Discussion of Results**

Priorities common to global and regional requirements are atmospheric observations of air temperature, precipitation and precipitation extreme events, clouds and aerosols; ocean observations of sea-surface temperature, sea level, and sea ice; and terrestrial processes of snow cover, glaciers and ice caps, land cover, and water use.

Observations of global but not regional priority are atmospheric variables of surface radiation budget, surface water vapor, earth radiation budget, upper air water vapor and greenhouse gases, and ocean variables of sea-surface salinity, carbon dioxide partial pressure, and subsurface carbon.

All of the terrestrial processes that are priority are regional priorities; some of these are also global priorities (but none are only global priorities).

**Table 10. Global and Regional Priorities.**

	GLOBAL *				REGIONAL
Observation	Accuracy	Spatial Resolution	Temporal Resolution	Stability**	
<b>The Atmosphere</b>					
<b>Surface</b>					
<i>Air Temperature</i>	N/A	N/A	N/A	N/A	N. America; Asia, Pacific Islands
<i>Precipitation</i>	0.1 mm h <sup>-1</sup>	100 km hor	3-hourly	0.6%/decade	N. America, Africa, Europe, Mediterranean Basin
<i>Precipitation extreme events</i>		1 km hor	10 minutes		N. America, Central and S. America, Caribbean, Africa, Asia, Pacific Islands, Mediterranean Basin
<i>Air pressure</i>	N/A	N/A	N/A	N/A	N. America, Pacific Islands
<i>Surface radiation budget</i>	N/A	N/A	N/A	N/A	
<i>Water vapor</i>	2% of local value	0.1 km ver <sup>a</sup>	3-hourly	0.3%/ decade	
<b>Upper Air</b>					
<i>Earth radiation budget</i>	1 Wm <sup>-2</sup> downwelling at TOA 5 Wm <sup>-2</sup> outgoing SW/LW at TOA	100 km hor	3-hourly	1 Wm <sup>-2</sup> over 5 yrs 0.2 Wm <sup>-2</sup> /decade	
<i>Water vapor</i>	2% local value 1 % total column	10 – 50 km hor 2 km ver	3-hourly	0.3%/decade	
<i>Cloud properties</i> Cover Ice profile (column) Water profile (column) Top height Top temperature	10%   0.5 km 0.3 K	100 km hor 100 km hor 100 km hor 100 km hor 100 km hor  30 – 50 m (NRC) <sup>k</sup> 1 km (NRC) <sup>k</sup>	3-hourly 3-hourly 3-hourly 3-hourly 3-hourly  Days (NRC)		N. America, Central and SE Asia

ORANGE = Global and Regional Priority    GREEN = Global Priority    YELLOW = Regional Priority

**Table 10. (Continued).**

	GLOBAL *				REGIONAL
Observation	Accuracy	Spatial Resolution	Temporal Resolution	Stability **	
Composition					
Carbon dioxide	3 ppm	10 – 250 km hor <sup>c</sup>	3-hourly	3-ppm (forcing) 1-ppm (sources and sinks)	
Methane	20 ppb	10 – 250 km hor <sup>c</sup>	3-hourly	3-ppm (forcing) 1-ppm (sources and sinks)	
Other long-lived greenhouse gases					
Aerosol properties	0.01 (optical depth)	1 km hor	Daily	0.005/decade	N. America, Africa, Asia
The Oceans					
Surface					
Sea-surface temperature	0.25°C	1 km hor	3-hourly	0.1°C	N. America, Central and S. America, Caribbean, Africa, S. and SW Asia, Pacific Islands
Sea-surface salinity					
Sea level	1 cm	25 km hor	Daily	0.5 mm/decade	N. America and Pacific Islands
Sea ice	5%	12 km hor	Daily	5%/decade	N. America and Europe
Carbon dioxide partial pressure	N/A	N/A	N/A	N/A	
Subsurface					
Carbon	N/A	N/A	N/A	N/A	

ORANGE = Global and Regional Priority    GREEN = Global Priority    YELLOW = Regional Priority

**Table 10. (Continued).**

Observation	GLOBAL *				REGIONAL
	Accuracy	Spatial Resolution	Temporal Resolution	Stability **	
<b>Terrestrial Processes</b>					
<i>Snow cover area</i>	5% <sup>d</sup> Better than 1/3 IFOV w/target IFOV 100 m (complex terrain) 1 km (elsewhere)	100 m hor (complex terrain) 1 km (elsewhere)	Daily	5% <sup>d</sup> Better than 1/3 IFOV w/target IFOV 100 m (complex terrain) 1 km (elsewhere)	N. America, Central and SE Asia, Europe
<i>Glaciers and ice caps</i> Area maps	5% <sup>d</sup> Better than 1/3 IFOV w/ target IFOV 30 m	30 m hor	1 yr	5% <sup>d</sup> Better than 1/3 IFOV w/ target IFOV 30 m	N. America, Central and S. America, Caribbean, Asia, Europe
Elevation changes	0.1 m	100 m hor	1 yr	0.1 m	
<i>Permafrost and seasonally-adjusted frozen ground</i>	N/A	N/A	N/A	N/A	
<i>Land cover</i> Type maps	15% <sup>e</sup> Better than 1/3 IFOV w/ target IFOV 250 m	250 m – 1 km hor	1-yr	15% <sup>e</sup> Better than 1/3 IFOV w/ target IFOV 250 m	N. America, Central and S. America, Caribbean, Africa, Africa, Europe, Asia, Mediterranean Basin
Change maps	5% <sup>e</sup> Better than 1/3 IFOV w/ target IFOV 10-30 m	10-30 m hor	5-yr <sup>f</sup>	5% <sup>e</sup> Better than 1/3 IFOV w/ target IFOV 10-30 m	
<i>Lakes</i>	N/A	N/A	N/A	N/A	N. America, Africa, Pacific Islands, Europe
<i>Soil Moisture</i>	N/A	N/A	N/A	N/A	N. America, Africa, Europe
<i>River discharge</i>	N/A	N/A	N/A	N/A	N. America, Africa, Pacific Islands, Europe
<i>Water use</i>	N/A	N/A	N/A	N/A	N. America, Africa, Pacific Islands, Mediterranean Basin
<i>Groundwater</i>	N/A	N/A	N/A	N/A	N. America, Africa, Europe
Notes <i>Essential Climate Variables in italics (see text for discussion)</i> *Technical requirements for global observations unless otherwise noted; source <i>GCOS 2006a</i> **Ability of the data to detect long-term trends <sup>a</sup> Planetary boundary layer <sup>c</sup> Troposphere to stratosphere <sup>d</sup> Maximum error of omission and commission in glacier area maps <sup>e</sup> Maximum error of omission and commission in mapping individual classes <sup>f</sup> Intervals should coincide with UNFCCC requirements <sup>k</sup> 30 – 50 m hyperspectral; 1 km polarimeter					

ORANGE = Global and Regional Priority    GREEN = Global Priority    YELLOW = Regional Priority

Observations of regional but not global priority are atmospheric air pressure and terrestrial processes of permafrost and seasonally-adjusted frozen ground, lakes, soil moisture, river discharge, and groundwater.

Some patterns are suggested by this comparison of global and regional priorities. The differences between them may reflect the difference between understanding and management of climate as “global public good” compared with the need to respond at the regional and national geographic scale to the effects of climate (see Barrett 2007; this point is also emphasized in WMO 2008a, which describes findings of a workshop between global climate modelers and scientists and experts involved in IPCC discussion of climate impacts and regional adaptation to a changing climate). The least overlap is with two sub-areas: (1) the global but not regional priority accorded many of the ocean observations (representing climate phenomena that may be of lesser impact than perceived at the regional and national scale) and (2) the regional/national but not global priority accorded terrestrial processes such as water use, groundwater, lakes, and river discharge. In the case of ocean observations, for which few have regional priority, the exceptions of regional significance of sea level and sea-surface temperature are likely correlated with their role in anticipating and responding to extreme natural weather events (as indicated in the contextual discussion in regional documents of the Western South Atlantic (WMO 2006), the Western Indian Ocean (WMO 2006 and Washington et al. 2004) and the problem of tsunamis in the Pacific Islands (WMO 2006)). Other ocean phenomena may be only indirectly regarded as required Earth observations for regional and national decisionmakers. This pattern could suggest not only a difference in importance based on geographic scale but perhaps time scale as well; events with near-term effects (extreme precipitation, water use) may be more important for regional and national governments than those with more subtle temporal effects (earth radiation budget, long-lived greenhouse gases).

Another notable result is the lack of regional and national priority accorded atmospheric observations of carbon dioxide and methane. This result may be explained by the yet-to-be developed policy responses to greenhouse gas mitigation by policymakers (but this would not explain why these observations do not show up as a priority for Europe, where an emissions permit trading regime is in place). Or, the result may be an artifact of the nature of the documents surveyed; the regional and national documents tend toward adaptation to a changing climate rather than reduction and control of greenhouse gases.

## **6 Additional Findings**

In tandem with the deepening understanding of climate as an integrated system of Earth’s processes, the number of ECVs has continued to grow (most recently, to include soil moisture). In addition, the priority observations identified in this report also overlap with many priority observations for weather (the Weather and Climate SBA analysts shared documents and exchanged ideas during the report preparation). Further analysis in the next stage of the overall UIC project may reveal significant overlap with priority observations for the other GEO SBAs, further demonstrating the overlap described in the Climate SBA in the GEOSS 10-Year Implementation Plan.

The Advisory Group has provided additional perspective on priorities for the Climate SBA other than those of observations. They note an ongoing emphasis in climate modeling and observations to emphasize downscaling of global observations – an action seen as extremely high priority. The AG also emphasizes that essential next steps include *reanalysis* -- an assessment of the effectiveness and use of existing climate records and modeling to identify their limits as climate science and information move into the future. Synoptic and continuous records from previous asynoptic and discontinuous measurements must also be created. The Group points out that in the future, inverting the usual continuum moving from observations to information to knowledge is also desirable– that is, asking first what information is required by decisionmakers and the public as they embark on the design of public policy to address a changing climate. The AG also notes that additional top priorities for understanding climate and of relevance to GEO societal benefit emphases are (1) developing archive, distribution, maintenance, reprocessing, and other procedures for the sound management of data and (2) sustaining observations over time.

## 7 Analysts Comments and Recommendations

### 7.1 Process and Methodology

#### 7.1.1. Process

##### Advisory Group:

Use of an Advisory Group was extremely helpful to guide the analyst and identify source material. The Advisory Group also generously shared perspectives on issues in requirements for understanding and managing climate in addition to the identification of priorities and provided the analyst with additional context.

##### Report template and outline:

The role of the UIC leadership in drafting and supplying a common template and detailed outline greatly streamlined the process of compiling the report.

##### Report audience:

The role of the UIC leadership in defining the audience for the report was essential.

#### 7.1.2. Methodology

##### Documents as a measure for tracking progress:

A measure requested of all analysts each month during the project was the number of documents obtained. The emphasis on compiling a large number of documents had advantages and disadvantages. The advantage was that by being encouraged to assemble a large number, the analyst had a commensurately larger amount of material, but the disadvantage is that the number of documents is not necessarily correlated with quality. In future tasks, some provision might be made for a quality ranking of documents as an additional component for tracking progress. (This



comment is offered in terms of tracking progress; during the conduct of the analysis, analysts were encouraged to work with the Advisory Group to consider the quality of the documents.)

#### Limitations on analyses drawn from written material:

The complexity of climate as interactions among Earth processes and the usefulness of coordinating observing systems have led to the use of large international working groups of experts to define priorities. The GCOS and its related activities have led much of this work to date. As WMO (2008a) demonstrates, the IPCC and GCOS are increasing their collaboration to better connect observations with policy, and to better connect observations with mitigation and adaptation actions. This means that large amounts of information are concentrated in a smaller number of documents than would have been the case in the absence of these collaborative efforts. How best to weight them or to adjust for commonly authored documents is a challenge in bibliometric approaches.

#### Identifying spatial, temporal, and other attributes of observations:

Information about the technical parameters of the observations was very limited. Only one document provided information for most of the observations; two additional documents provided technical information but of lesser detail and only for a few observations.

#### Identifying priorities:

A methodology based on a count of documents, when the number is as small as the number used in this task, led to use of simple counts as the most transparent method for aggregating requirements and identifying priorities. The advantage of this approach is that it avoids errors or biases in judgement on the part of the analyst. Readers have available the list of documents and can judge for themselves how representative the count approach is. The disadvantage is that contextual information in the documents and broader perspectives offered by the Advisory Group were difficult to integrate. Another disadvantage of an approach based on a small number of documents is that the method is not robust; it is sensitive to the number and quality of documents.

## **7.2 Challenges**

At present, comprehensive and detailed information on regional and smaller spatial scale priority observations has yet to be collected and assembled. The regional priorities identified in this report are drawn from a very small number of documents. The gap is recognized in the literature (for example, see WMO, 2006; IPCC 2007c; NRC 2009).

Another challenge is the gap between the science and application of observations, in both identifying requirements and setting priorities. This report sought to help in closing the gap by specifying both climate modellers and the policy community as two user types, and compiling and reviewing documents from both.

Identifying priorities for the climate SBA is also a step that some members of the Advisory Group saw in light of a more immediate set of priorities, as noted in Section 6.

## **Appendix A: Abbreviations**

AG	Advisory Group
CEOS	Committee on Earth Observation Satellites
ECVs	Essential Climate Variables
ESA	European Space Agency
ESF	European Science Foundation
GCOS	Global Climate Observing System
GEF	Global Environmental Facility
GEO	Group on Earth Observation
GEOSS	Global Earth Observation System of Systems
GMES	Global Monitoring for Environment and Security
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observing System
IGBP	International Exosphere-Biosphere Program
IPCC	Intergovernmental Panel on Climate Change
MSCES	Meteorological Service of Canada – Environment Canada
NRC	National Research Council
RFF	Resources for the Future
SBA	Societal Benefit Area
UIC	User Interface Committee
UNFAO	United Nations Food and Agriculture Organization
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Program
WMO	World Meteorological Organization

## Appendix B: Bibliography

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## Appendix C: List of Documents with URL and Document Category

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
Bojinski et al 2008	III	Key Needs for Observing Climate Change from Space	Bojinski, Stephan	September 2008	Presentation	International	<a href="http://www.sapc.jaxa.jp/about/data/eoseminar02_04.pdf">http://www.sapc.jaxa.jp/about/data/eoseminar02_04.pdf</a>
CEOS 2006	I	Satellite Observation of the Climate System: The Committee on Earth Observation Satellites (CEOS) Response to the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC	CEOS	September 2006	Report	International	<a href="http://www.ceos.org/images/PDFs/CEOSResponse_1010A.pdf">http://www.ceos.org/images/PDFs/CEOSResponse_1010A.pdf</a>
Cfu et al 2006	IV	Initial Science Plan of the Monsoon Asia Integrated Regional Study	Cfu, Congbin and Frits Penning De Vries (eds)	2006	Report	Regional/Asia	<a href="http://www.mairs-essp.org/UserFiles/File/isp-1.1.pdf">http://www.mairs-essp.org/UserFiles/File/isp-1.1.pdf</a>
ESA 2007a	IV and V	Sentinel-2: Mission Requirements Document (issue 2 revision 0)	ESA	February 2007	Mission Requirements Document	Regional/Europe	<a href="http://esamultimedia.esa.int/docs/GMES/GMES_Sentinel3_MRD_V2.0_update.pdf">http://esamultimedia.esa.int/docs/GMES/GMES_Sentinel3_MRD_V2.0_update.pdf</a>
ESA 2007b	V	GMES Sentinels 4 and 5 Mission Requirements Document (issue 1 revision 0)	ESA	April 2007	Mission Requirements Document	Regional/Europe	<a href="http://esamultimedia.esa.int/docs/GMES/Sentinel4and5MRDissue1rev0signed.pdf">http://esamultimedia.esa.int/docs/GMES/Sentinel4and5MRDissue1rev0signed.pdf</a>
ESF 2008	IV	Recommendations to the Ministerial Conference of ESA Member States	European Science Foundation	November 2008	Report	Regional/Europe	<a href="http://www.esf.org/nc/publications/space.html?tx_ccdamdl_cart[add]=20102">http://www.esf.org/nc/publications/space.html?tx_ccdamdl_cart[add]=20102</a>
Federal Service 2008	IV	Assessment Report on Climate Change and its Consequences in Russian Federation	Federal Service for Hydrometeorology and Environmental Monitoring, Russian Federation	2008	Report	Regional/Russia	<a href="http://climate2008.igce.ru/v2008/pdf/resume_ob_eng.pdf">http://climate2008.igce.ru/v2008/pdf/resume_ob_eng.pdf</a>



Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
GCOS 2006a	I	Systematic Observation Requirements for Satellite-based Products for Climate - Supplemental details to the satellite-based component of the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-107)	GCOS	September 2006	Report	International	<a href="http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf">http://www.wmo.int/pages/prog/gcos/Publications/gcos-107.pdf</a>
GCOS 2006b	IV	Climate Information for Development Needs: An Action Plan for Africa	GCOS and partners	November 2006	Report	Regional/Africa	<a href="http://www.wmo.int/pages/prog/gcos/Publications/gcos-108.pdf">http://www.wmo.int/pages/prog/gcos/Publications/gcos-108.pdf</a>
GCOS 2009a	I	Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements	GCOS Secretariat	March 2009	Report	International	<a href="http://www.wmo.int/pages/prog/gcos/documents/GCOS_Guideline_DatasetsProducts_March2009.pdf">http://www.wmo.int/pages/prog/gcos/documents/GCOS_Guideline_DatasetsProducts_March2009.pdf</a>
GCOS 2009b	I	Progress Report on the Implementation of the Global Observing System for Climate in Support of the UNFCCC 2004-2008	GCOS Secretariat	April 2009	Report	International	<a href="http://www.wmo.int/pages/prog/gcos/Publications/GCOSProgressReport_ReviewDraft_080409.pdf">http://www.wmo.int/pages/prog/gcos/Publications/GCOSProgressReport_ReviewDraft_080409.pdf</a>
GCOS 2009c	I	GCOS Essential Climate Variables	GCOS	26 May 2009	Table	International	<a href="http://www.wmo.ch/pages/prog/gcos/index.php?name=essentialvariables">http://www.wmo.ch/pages/prog/gcos/index.php?name=essentialvariables</a>
GEF 2004	IV	It's Raining, It's Pouring, It's Time to Be Adapting: Report of the 2nd Assessment of Impacts and Adaptation to Climate Change (AIACC) Regional Workshop for Latin America and the Caribbean	Global Environmental Facility/AIACC	August 2004	Report	Regional/Latin America/Caribbean	<a href="http://www.aiaccproject.org/meetings/Buenos_Aires_04/Buenos_Aires.pdf">http://www.aiaccproject.org/meetings/Buenos_Aires_04/Buenos_Aires.pdf</a>
GEO 2009	I	Climate Achievements	GEO, members, and participating organizations	Ongoing	Status briefs	Regional	<a href="http://www.earthobservations.org/geoss_cl_ea.shtml">http://www.earthobservations.org/geoss_cl_ea.shtml</a>
Hamazaki 2008	III	JAXA Space Agency Contributions to Global Monitoring of Greenhouse Gases	Hamazaki, Takashi	September 2008	Presentation	International	<a href="http://sapc.jaxa.jp/about/data/eoseminar02_06.pdf">http://sapc.jaxa.jp/about/data/eoseminar02_06.pdf</a>

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
IPCC 2007a	II	Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	IPCC	2007	Report	International	<a href="http://www.ipcc.ch/ipccreports/ar4-wg2.htm">http://www.ipcc.ch/ipccreports/ar4-wg2.htm</a>
IPCC 2007b	II	Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	IPCC	2007	Report	International	<a href="http://www.ipcc.ch/ipccreports/ar4-syr.htm">http://www.ipcc.ch/ipccreports/ar4-syr.htm</a>
IPCC 2007c	II	Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	IPCC	2007	Report	International	<a href="http://www.ipcc.ch/ipccreports/ar4-wg1.htm">http://www.ipcc.ch/ipccreports/ar4-wg1.htm</a>
Karl et al 2009	IV	Global Climate Change Impacts in the United States	Karl, Thomas R. Et al	2009	Report (published by Cambridge University Press)	Regional/USA	<a href="http://www.globalchange.gov">http://www.globalchange.gov</a>
Khare 2008	VI	Earth Observations: A Catastrophe Risk Modeling Point of View	Khare, Shree	July 2008	Presentation	International	<a href="http://www.csis.org/media/isis/events/080716_RMS.pdf">http://www.csis.org/media/isis/events/080716_RMS.pdf</a>
Long et al 2007	IV and V	CPC's Climate Monitoring Needs and the Certified NPOESS Program	Long, Craig S., Wayne Higgins, John Janowiak, S.K. Yang	October 2007	Presentation	Regional/USA	<a href="http://www7.nationalacademies.org/ssb/NPOESS_mitigate_descope_presentation_Long.pdf">http://www7.nationalacademies.org/ssb/NPOESS_mitigate_descope_presentation_Long.pdf</a>
Maynard 2008	VI	Global Data and Why Insurers Need It	Maynard, Trevor	July 2008	Presentation	International	<a href="http://www.csis.org/media/isis/events/080716_lloyd.pdf">http://www.csis.org/media/isis/events/080716_lloyd.pdf</a>

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
MSCES 2008	IV	The Canadian National Report on Systematic Observations for Climate: National Activities with Respect to the Global Climate Observing System (GCOS) Implementation Plan	Meteorological Service of Canada- Environment Canada	November 2008	Report	Regional/Canada	<a href="http://unfccc.int/resource/docs/gcos/cangcose.pdf">http://unfccc.int/resource/docs/gcos/cangcose.pdf</a>
NRC 2007	IV and V	Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future, National Research Council	National Research Council of the National Academies	2007	Report	International and Regional/USA	<a href="http://www.nap.edu/catalog.php?record_id=11820">http://www.nap.edu/catalog.php?record_id=11820</a>
NRC 2008	V	Ensuring the Climate Record from the NPOESS and GOES-R Spacecraft	National Research Council of the National Academies	2008	Report	International	<a href="http://www.nap.edu/catalog.php?record_id=12254#toc">http://www.nap.edu/catalog.php?record_id=12254#toc</a>
NRC 2009	IV and V	Informing Decisions in a Changing Climate	National Research Council of the National Academies	2009	Report	Regional/USA	<a href="http://www.nap.edu/catalog.php?record_id=12626">http://www.nap.edu/catalog.php?record_id=12626</a>
Ohring et al 2007	I	Achieving Satellite Instrument Calibration for Climate Change (ASIC3)	Ohring, George (ed.)	2007	Report	International	<a href="http://www.star.nesdis.noaa.gov/star/documents/ASIC3-071218-webversfinal.pdf">http://www.star.nesdis.noaa.gov/star/documents/ASIC3-071218-webversfinal.pdf</a>
Patton 2008	VI	Earth Observation, Global Change and Insurance	Patton, Lindene	July 2008	Presentation	International	<a href="http://www.csis.org/media/isis/events/080716_zurich.pdf">http://www.csis.org/media/isis/events/080716_zurich.pdf</a>
Salinger et al 2002	IV	Pacific Island GCOS Action Plan	Salinger, Jim et al.	March 2002	Report	Regional/Pacific Islands	<a href="http://www.wmo.int/pages/prog/gcos/documents/PI-GCOS_AP.pdf">http://www.wmo.int/pages/prog/gcos/documents/PI-GCOS_AP.pdf</a>
Stott 2008	VI	Observations for Climate Monitoring, Attribution and Prediction	Stott, Peter	July 2008	Presentation	International	<a href="http://www.csis.org/media/isis/events/080716_hadley.pdf">http://www.csis.org/media/isis/events/080716_hadley.pdf</a>

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
UNFAO 2008a	I	Terrestrial Essential Climate Variables for Climate Change Assessment, Mitigation and Adaptation	UNFAO	2008	Report	International	<a href="http://www.fao.org/docrep/011/i0197e/i0197e00.htm">http://www.fao.org/docrep/011/i0197e/i0197e00.htm</a>
UNFCCC 2008b	II	Report of the Conference of the Parties on Global Observing Systems for Climate	UNFCCC	14 March 2008	Report	International	<a href="http://unfccc.int/resource/docs/2007/cop13/eng/06a02.pdf">http://unfccc.int/resource/docs/2007/cop13/eng/06a02.pdf</a>
Washington et al 2004	IV	Africa Climate Report	Washington, Richard et al.	December 2004	Report	Regional/Africa	<a href="http://www.defra.gov.uk/environment/climatechange/internat/devcountry/pdf/africa-climate.pdf">http://www.defra.gov.uk/environment/climatechange/internat/devcountry/pdf/africa-climate.pdf</a>
WCRP 2008	III	Report from the Third Meeting of the WCRP Observation and Assimilation Panel (WOAP)	WCRP	November 2008	Report	International	<a href="http://www.wmo.int/pages/prog/gcos/Publications/gcos-125.pdf">http://www.wmo.int/pages/prog/gcos/Publications/gcos-125.pdf</a>
WCRP 2009	IV	Workshop on Evaluating and Improving Regional Climate Projections	World Climate Research Program	February 2009	Report	International	<a href="http://wcrp.ipsl.jussieu.fr/Workshops/Downscaling/index.html">http://wcrp.ipsl.jussieu.fr/Workshops/Downscaling/index.html</a>
WCRP no date	IV	Monsoon Asia Integrated Regional Study	Earth System Science Partnership	No date	Report	Regional/Asia	<a href="http://www.mairs-essp.org/UserFiles/File/Brochure-new.pdf">www.mairs-essp.org/UserFiles/File/Brochure-new.pdf</a> and also <a href="http://www.mairs-essp.org/">http://www.mairs-essp.org/</a>
WMO 2004	I	Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (GCOS-92)	WMO	October 2004	Report	International	<a href="http://www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP_ES.pdf">http://www.wmo.int/pages/prog/gcos/Publications/gcos-92_GIP_ES.pdf</a>
WMO 2006	IV	Final Report of the GCOS Regional Workshop Programme (GCOS – 111B, WMO/TD No. 1474)	WMO	August 2006	Report	International and Regional	<a href="http://www.wmo.ch/pages/prog/gcos/Publications/gcos-111B.pdf">http://www.wmo.ch/pages/prog/gcos/Publications/gcos-111B.pdf</a>
WMO 2008a	III	Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report. GCOS-117, WCRP-127, IGBP Report No. 58 (WMO/TD No. 1418),	WMO	January 2008	Report	International	<a href="http://www.wmo.int/pages/prog/gcos/Publications/gcos-117.pdf">http://www.wmo.int/pages/prog/gcos/Publications/gcos-117.pdf</a>

Reference	Doc Class	Title	Author	Year Published	Type of Document	Region	File
WMO 2008b	IV	An International Expert Review Meeting on Regional Climate Outlook Forums	WMO	November 2008	Report	International and Regional	<a href="http://www.wmo.int/pages/prog/wcp/wcasp/documents/RCOFReview2008ConceptNote.pdf">http://www.wmo.int/pages/prog/wcp/wcasp/documents/RCOFReview2008ConceptNote.pdf</a>
WMO 2008c	I	The Space-Based Global Observing System in 2008 (GOS-2008).	WMO	October 2008	Report	International	<a href="ftp://ftp.wmo.int/Documents/PublicWeb/sat/DossierGOS-2008_Volumes-0-1-2-3-4.zip">ftp://ftp.wmo.int/Documents/PublicWeb/sat/DossierGOS-2008_Volumes-0-1-2-3-4.zip</a>
WMO 2009	I	The Space-Based Global Observing System in 2009 (GOS-2009).	WMO	June 2009	Report	International	<a href="ftp://ftp.wmo.int/Documents/PublicWeb/sat/DossierGOS/Gos-2009-June.zip">ftp://ftp.wmo.int/Documents/PublicWeb/sat/DossierGOS/Gos-2009-June.zip</a>

## Appendix D: Results of Relative Citation Frequency

Citation Frequency of Global and Regional Requirements (see text for method)		
Observation	Global	Region
<b>The Atmosphere</b>		
<b>Surface</b>		
Air temperature	.2	.4
Precipitation	.3	.6
Precipitation extreme events	.3	.8
Air pressure	.1	.2
Surface radiation budget	.2	.1
Wind speed and direction	.1	.1
Water vapor	.3	0
Evaporation and evapotranspiration	.1	0
<b>Upper Air</b>		
Earth radiation budget	.3	0
Upper air temperature	.1	0
Wind speed and direction	.1	0
Water vapor	.3	0
Cloud properties	.3	.2
Cover		
Ice profile (column)		
Water profile (column)		
Top height		
Top temperature		
<b>Composition</b>		
Carbon dioxide	.4	0
Methane	.4	0
Ozone	.2	.1
Other long-lived greenhouse gases	.4	0
Aerosol properties	.3	.6
<b>The Oceans</b>		
<b>Surface</b>		
Sea-surface temperature	.3	.7
Sea-surface salinity	.2	0
Sea level	.4	.2
Sea state	.1	0
Sea ice	.3	.2
Current	.1	0
Ocean color	.1	0
Carbon dioxide partial pressure	.2	0
CO <sub>2</sub> flux across air/sea interface	.1	0
<b>Subsurface</b>		
Temperature	.1	.1
Salinity	.1	0
Current	.1	0
Nutrients	.1	.1
Carbon	.3	0
Ocean tracers	.1	0
Phytoplankton	.1	0

<b>Citation Frequency of Global and Regional Requirements (see text for method)</b>		
<b>Observation</b>	<b>Global</b>	<b>Region</b>
Terrestrial Processes		
Snow cover area	.3	.3
Glaciers and ice caps	.3	
Area maps		
Elevation changes		
Permafrost and seasonally-adjusted frozen ground	.1	.2
Albedo	.1	0
Land cover	.3	.8
Type maps		
Change maps		
Fraction of absorbed photo-synthetically active radiation	.1	0
Leaf area index	.1	0
Biomass	.1	0
Fire disturbance	.1	.1
Lakes	.1	.6
Level		
Surface temperature		
Soil moisture	.1	.4
River discharge	.1	.6
Water use	.3	.4
Groundwater	.1	.4
Land/soil carbon	.1	0